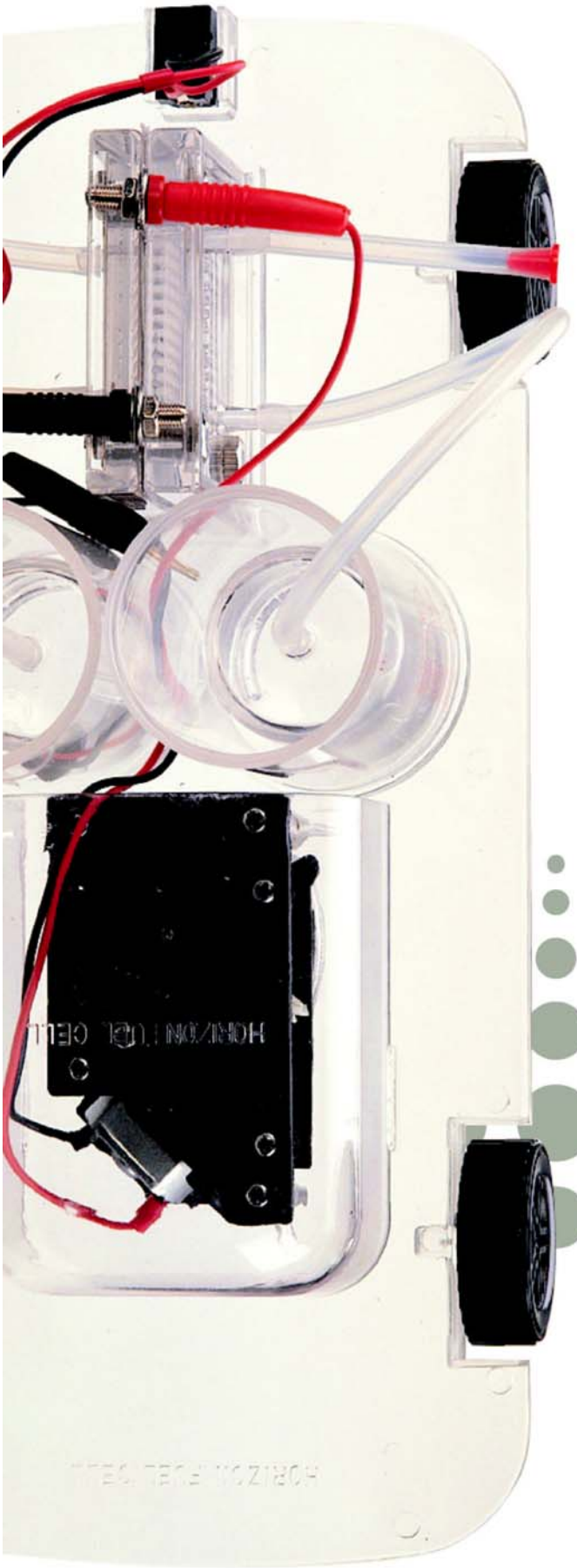

intelligent fuel cell car

EXPERIMENT MANUAL

RECOMMENDED FOR AGES 12+

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Intelligent Fuel Cell Car Lab

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Horizon Fuel Cells
China

Table of Contents

INTELLIGENT FUEL CELL CAR LABORATORY INSTRUCTIONS

READ ALL INSTRUCTIONS BEFORE USE

The Fuel Cell Car Lab has been developed to provide the safe study of hydrogen fuel cell technology. Special care must be taken to maintain a safe study environment.

1. Always work with adult supervision.

2. Protect your eyes! Use safety goggles. Anytime you are perform ing experiments of any kind, eye protection is important.

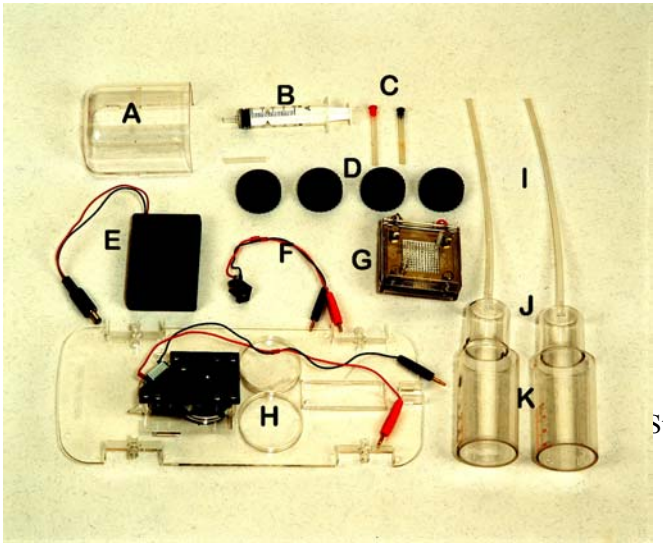
3. Never work around sparks or flames. Hydrogen and oxygen are extremely flammable. Even though they are contained safely in this kit, it is important to take caution.

4. Follow instructions. The instructions in this manual are structured to provide the safest environment for you and to preserve the equipment.

5. Turn off the battery pack when not in use. When the battery is turned on, do not allow the metal leads to touch, this could cause the battery to overheat resulting in skin burns, plastic melting and fire danger. Remove the batteries during storage.

6. Empty all water, hydrogen and oxygen from each component be fore storage.

LIST OF PARTS



A—Motor cover
B—Syringe
C—Lower tubes
D—Wheels
E—Power Supply
F—Power Supply leads
G—Fuel Cell (.3watts, 350mA)
H—Chassis
I—Upper Tubes
J—Inner Cylinders
K—Outer Cylinders

Intelligent Fuel Cell Car

Operating Instructions

Preparation:

Items you need that are not included in the kit::

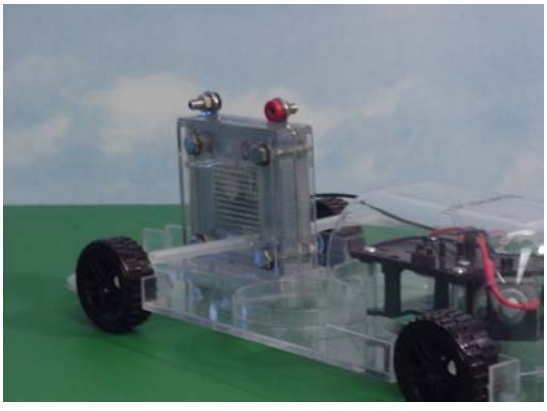
2 AA Batteries
100 ml distilled water (You can purchase this at your local grocery store. Purified water is NOT the same—it must be Distilled)

Step 1 Remove the back of the battery power pack. Insert two AA Batteries.

Step 2 Snap the wheels and the motor cover onto the chassis.

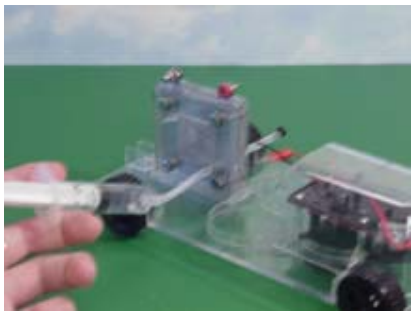
Step 3 Attach the small tube with the black plug to the bottom nozzle on the hydrogen side of the fuel cell. Attach the small tube with the red plug to the bottom nozzle on the oxygen side of the fuel cell. Remove the plugs from the tubes.

Step 4 Insert the fuel cell with the attached tubes into the rectangular slot on the car chassis so the tubes extending from the fuel cell are in front of the wheels and not on top of the wheels.



Operating Instructions

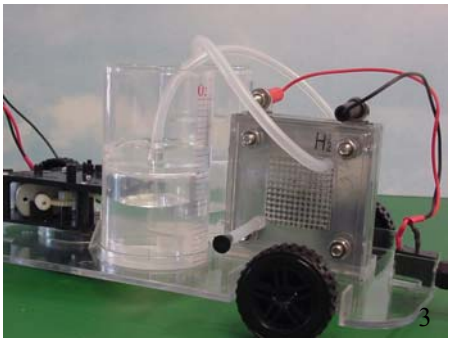
Step 5 Using the syringe, push water (about one ml) into the hydrogen side of the fuel cell until you see water filling the chamber in front of the screen. Repeat this on the oxygen side of the fuel cell



Step 6

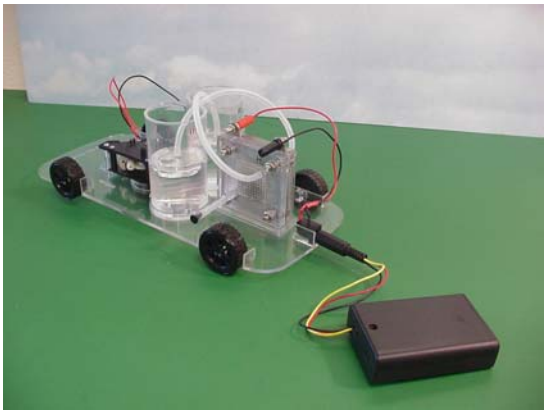
Insert the hydrogen and oxygen outer storage cylinders into the round slots on the chassis. Fill the cylinders to the zero mark on each of the cylinders. Insert the inner cylinders into the outer cylinders so the inner cylinders are filled with water. There are two notches at the bottom of each of the inner cylinders. Be sure these are not blocked by the raised plastic frame for the inner cylinders. The opening allows gas to escape the inner cylinder into the outer cylinder for storage. Push on the top of the inner cylinders to be sure they are fit snuggly onto the rim at the bottom of the outer cylinder.

Step 7 Attach the long tube coming from the top of the hydrogen storage cylinder to the upper nozzle on the hydrogen side of the fuel cell. Repeat this on the oxygen side of the fuel cell. We prefer to put the hydrogen cylinder on the car chassis on the side opposite the hydrogen side of the fuel cell so that the tubes cross, giving the fuel cell and cylinders a little more stability.



Operating Instructions

Step 8 Attach the plug from the battery pack into the power jack on the front of the car chassis. Insert the red and black wires from the power jack into the red and black banana jacks on the fuel cell.

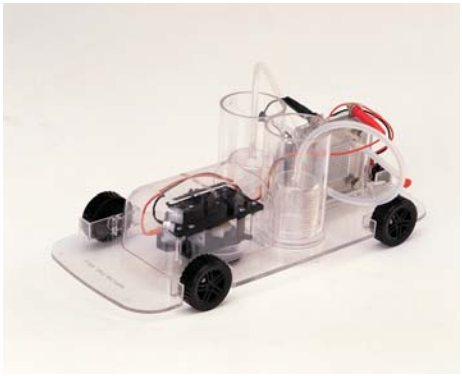


Step 9 Hydrogen and Oxygen are invisible. You will know gas is being produced when water is displaced to the top of the storage cylinders. You can measure the gas produced by measuring what looks like empty space increasing in the bottom of the cylinders, or by measuring the amount of water displaced to the top of the cylinder.

Step 10 When the hydrogen cylinder is filled, you will begin to see bubbles being released from the top of the hydrogen cylinder. Turn the battery pack off. Unplug the wires from the fuel cell and remove the power jack from the front of the fuel cell.

Operating Instructions

Step 11 Plug the red and black wires from the car motor to the red and black banana jacks on the fuel cell. If the lower tubes are touching the wheels, tuck the tube behind the small plastic cube that holds the wheel in place. Put the car on a flat surface and watch it go! When the car hits a barrier, it will turn 90 degrees and keep moving. Note: You will not have maxi mum performance until you have used the car three or four times. This is because the PEM membrane becomes better hydrated once it has been used. You can produce hydrogen and oxygen two or three times before adding additional water to the fuel cell. Just be sure the reservoir is at least 3/4 full with distilled water before electrolyzing.



Step 12 When you are finished working with the Intelligent Fuel Cell Car, shake excess water from the fuel cell. Disconnect the power jack from the battery pack. Remove the batteries from the battery pack.

Intelligent Fuel Cell Car

Tips for Success

1. **Your car will run for a longer period of time if it is on a smooth surface. If it is on a rough surface, like a carpet, it has more resistance and will go slower and for a shorter period of time. Also, turning requires a larger amount of energy for the car, so the fewer turns it has to make, the longer will run.**
2. **In electrolyser mode, make sure you fill the fuel cell with water each time you use the electrolyser. It is normal for your fuel cell to have minimal power the first few times you use it. This is because the fuel cell is not well hydrated. Go through the complete cycle of electrolysis/car motor a number of times before you do any initial measurements.**
3. **Make sure the small outlets on the inner cylinders are not blocked by the plastic rim on the bottom of the outer cylinder. The water uses these small holes to escape to the outer cylinder. Hydrogen and Oxygen are lighter than water, so they flow to the top of the inner tube and the water has to go somewhere. If these small holes are blocked, too much pressure will build in the fuel cell and you can damage the fuel cell.**
4. **When you run the fuel cell multiple times, water in the upper part of the outer cylinder might not descend to the inner cylinder. This is because a vacuum has been created in the tubing. Disconnect the tubing from the upper nozzle of the fuel cell and the water will descend into the inner cylinder.**
5. **Use only the power source provided. The power source has a resistor in it that reduces the power of 2 AA Batteries. The fuel cell requires 1.6 volts to work as an electrolyser. However, more than 2 volts going into the fuel cell can damage the membrane. The car will work with more voltage, but you will shorten the life of your fuel cell.**
6. **It is very important to only use distilled water. Other water includes minerals that will destroy the membrane. If you see brown or orange rust forming in your fuel cell, that means someone did not use distilled water.**

Intelligent Fuel Cell Car
Trouble Shooting

Problems	Solutions
Water levels do not drop when the gas outlet tubes on both sides of the fuel cell are un-plugged	Check whether the holes on the wall of the inner tanks of are blocked.
Electrolyser does not produce hydrogen and oxygen	Check whether the wires are appropriately con-nected, and whether there are loose connections. The fuel cell could be totally destroyed if the red wire of the battery pack is connected to the black pole of the fuel cell.
	Check whether the switch of the battery pack is on the "On" position.
Water electrolysis process slows down	Add water to the oxygen side of the fuel cell and wait for about 1 minute.
	Change batteries if the voltage of the battery pack is less than 1.65V. Usually new batteries will run out after 4-5 times of charges.
The car doesn't move after hy-drogen and oxygen are filled and the motor is connected to the fuel cell	Check the wiring.
The car stops moving while there's still hydrogen left inside the tanks	Purge the gases and do water electrolysis for 4-5 minutes, unplug the hydrogen gas outlet tube and oxygen gas outlet tubes to purge the gases. Do the water electrolysis again until the hydrogen tank is filled, and connect the motor to the fuel cell. If the problem continues, go to the next step.
	Let the water electrolysis process last 10 minutes, to consume the residual water and to push water out of the fuel cell, purge the gases. Do water elec-trolysis again until the hydrogen tank is filled, con-nect the motor to the fuel cell.
The car only makes turns and does not move forward	Put the fuel cell car on a surface with better adher-ence. If the problem continues, go to the next step.
	Add 50-100 grams of load to the front part of the car

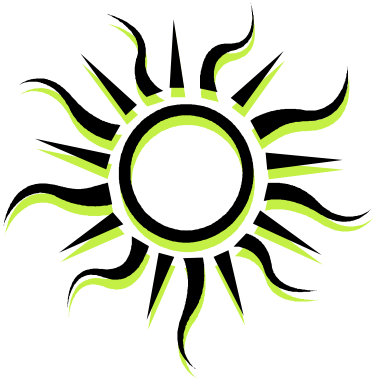
Still having problems? Call FuelCellStore.com at 303 237.3834

RENEWABLE ENERGY

With a practically never-ending supply of energy, and an efficient way of storing it, the days of fossil fuels may be numbered.

SOLAR Energy

One hundredth of one millionth of one percent is more than enough.

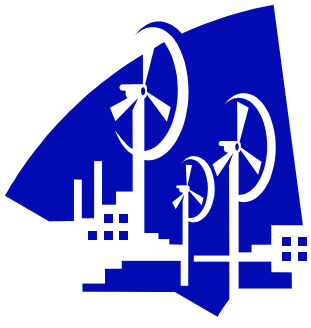


The amount of energy that the sun produces is staggering (Earth receives only 0.00000001% of it!). But just that little bit is enough to power everything we use. There are a few different ways to harness our little piece of the solar energy pie. Photovoltaic (PV) cells are the most common, converting light directly to usable electricity. However, it can also be used to create tremendous amounts of heat to run an industrial gas turbine, heat a local swimming pool, or even simple baseboard heating for an apartment.

However, there are obstacles to overcome and their price is still among the most expensive renewable energies. But there is also a great amount of promise in solar energy. Research has drastically increased the abysmal efficiencies of a few years ago and architects and engineers are beginning to design more dynamic and resourceful structures to utilize the heating powers of the sun.

WIND Energy

From sailboats to 5 gigawatt hour windmills, wind energy systems are growing at a break-neck pace.



Wind energy is the fastest growing source of energy in the world, and for good reason. Being around since the first sailboat, research in the field of wind technology has done drastic improvements: wind energy is now the cheapest form of renewable energy at around 4 cents per kilowatt hour (much less than 10-15 cents for solar PV cells). With such a competitive advantage, wind power is poised for a very rapid growth. Growth hasn't just applied to the percentage of energy produced by wind (around 5% of U.S. output in 2004) but also in the output of the machine itself from 45 megawatt hours per year (1981) to 5,600 megawatt hours (2000).

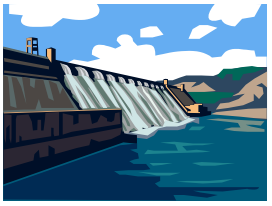
While riding this wave of development, there's no reason to back down now. Further growth and new research and development is being done through off shore wind farms including a large farm off the coast of Ireland that can power over 16,000 homes.

GEOTHERMAL Energy
Not a new kid on the block — it is right under our feet!

After the first geothermal power plant in 1904 began powering its local Italian countryside, the flood gates of research were opened. Of course, the ability to use geothermal power had been around for sometime. Over 10,000 years ago, Native Americans used local hot springs to cook their food. Romans used the warmth from under Pompeii to heat their houses. But the birth of the modern geothermal power plant opened to door to being truly effective. Using the heated water from geothermal reservoirs, steam powers turbines producing completely clean energy.

Unfortunately, the limited sites for the effective use of geothermal energy have hampered the research and development of this technology. Currently there are approximately 8 megawatts of geothermal energy being utilized as opposed to the 40,000 megawatts of wind farms. But there is hope. The amount of viable sites is growing much faster than the power plant bilding can keep up with. A ten fold increase in production is well within sight.

HYDRO ELECTRIC Energy
Providing more power than any other renewable source is no excuse to rest.



Without question, water turbine energy has already proved its usefulness throughout the world. In 2004 over 715,000 megawatts of power, an astounding 19% of the world's energy was produced from the flow of water through turbines. But there's no stopping there. Another 17,000 megawatts will be produced from the Three Gorges Dam of the Yangtze River, not to mention hundreds of proposed hydroelectric sites that are slated for utilization. This time tested technology has been amplified with the staggering efficiencies of the turbines themselves (over 90%) and its completely renewable power sources; water and gravity.

Despite the fact that this energy has proven its worth, there are still questions with the development of each new site. While entirely renewable, the damming of rivers is far from what could be considered "green" power with the sever interruption of many of the rivers natural processes. However, water turbines have proved a valuable renewable energy tool and will likely continue into the future.

FUEL CELL Energy
The common currency in which all renewable energy can be invested.

Of course, there are people that live where it's always overcast, never windy, in the middle of a tectonic plate, and without any viable dam spots. That quickly limits the ability of solar, wind, geothermal or water turbine energy to become the "energy of the future". However, there is one energy currency that could be tapped to assist those in less desirable climes. Hydrogen can be made using renewable energy sources, stored, and shipped anywhere in the world to power a fuel cell giving a truly renewable source of energy to even the unfortunately placed.

While this may be the solution, there are still kinks to work out. Expensive platinum is currently required for the fuel cell reaction, power density is less than stellar and storage of hydrogen is a daunting task. Nevertheless, giant strides are being made in every facet of the technology with billions of dollars flowing into research and development in both the private and public sector.

THE FUEL CELL TIMELINE

From lonely experiment, to space traveler, to the shape of things to come; this is the history of the technology that will power the future.

Visit these websites for more information

Nicholson and Carlisle

www.chemforlife.org/teacher/topics/hydrogen_rocket.htm

chem.ch.huji.ac.il/~eugeniik/history/nicholson.html

William Grove

www.generalhydrogen.com/tech_fuelcells.shtml

Edwin Drake

www.pbs.org.wbgh/theymadeamerica/whomade/drake_hi.html

Ostwald

americanhistory.si.edu/fuelcells/origins/orig2.htm

Baur and Preis

americanhistory.si.edu/fuelcells/so/sofmain.htm

PEMFCs

www.humboldt.edu/~serc/animation.htm/

1800
Fuel Cell Infancy

Nicholson and Carlisle separate water into oxygen and hydrogen in the first experiment of electrolysis. **1838** William Grove creates his "wet cell" battery using platinum, nitric acid, zinc, and sulfur. This is a tremendous step towards the eventual creation of the fuel cell. **1840** Morse creates his famous code and the telecommunications industry, the first mass need for power. Coal becomes the fuel of choice sealing the fate of "green" power for years to come. **1843** Grove continues his research in battery technology and stumbles across a new type. With platinum electrodes, sulfuric acid, hydrogen and oxygen, he creates his "gas battery" a way of reversing electrolysis. History will call it the fuel cell.

1850
Fuel Cells on the Back Burner

1859 Edwin Drake drills the first successful oil well in Pennsylvania. The well is only 69 feet deep, but produces yet another cheap competitor that will further deflate fuel cell research. **1860** Hundreds of company follow the lead of Drake and create wells all across the nation. Over 500,000 barrels of oil are produced and is followed by exponential growth for years to follow. Between coal and oil, energy questions seem answered, further wounding fuel cell research. **1893** Ostwald concludes his paper on the physical chemistry of the reaction inside the fuel cell connecting the various components to their actions. While an important piece in the line, it was hypothesized by Grove fifty years ago. The technology of fuel cells remains stagnant. **1896** Jacques claims to invent "a process of making electricity directly from coal" though it is quickly debunked as a small thermoelectric action.

1900
The Electrolyte Explosion

1930s Baur and Preis begin to experiment with different electrolytes with growing attention to what would eventually become Solid Oxide Fuel Cells (SOFC). Despite attempting electrolytes using yttrium, cerium, lanthanum and tungsten, unwanted chemical reactions continue. **1937** The Hindenburg explodes on May 6th bringing bad press for hydrogen. It was later proved that the covering of the zeppelin was to blame, not the hydrogen. **1938** Teflon is developed by DuPont which steps toward Nafion, a key component in the development of Proton Exchange Membrane Fuel Cells (PEMFC). At the same time, Francis Bacon begins experimentation with potassium hydroxide as an electrolyte with dramatically increases the power density of the fuel cell. **1940s** Davtyan begins serious research into SOFCs using monazite, sodium carbonate and tungsten trioxide. However, problems still occur with unwanted chemical reactions and lifetimes.

1950
On the Way to Niche Markets

1957 Broers and Ketelaar abandon the SOFC research of Davtyan and others due to its stubbornness with the solvency of unwanted chemical reactions and lifetime issues. They begin the field of Molten Carbonate Fuel Cells (MCFC). **1959** To combat the growing ill will towards SOFCs, a fuel cell symposium involving the Central Technical Institute, Consolidation Coal Company and General Electric is convened. However, it quickly becomes an almost universal agreement that SOFCs are not worth the trouble and to begin working on MCFCs as quickly as possible. Staying above the fray, Allis-Chalmers begins to outfit its tractor with 1,008 Alkali Fuel Cell (AFC) giving it 15,000 watts. They continue their niche market with a golf cart, personal submarine, and fork lift.

1960
The Renaissance of the Fuel Cell

1960 Broers and Ketelaar announce that their new MCFC has been running continuously for six months, drastically besting the lifetime of SOFCs. Materials in the gaskets begin to show trouble, but the improvement over SOFC is large. **1961** Elmore and Tanner publish "Intermediate Temperature Fuel Cells" revolutionizing research in Phosphoric Acid Fuel Cells (PAFC). Their work greatly increased the power density of fuel cells. **1965** The U.S. Army begins testing of a MCFC produced by Texas Instruments which can run off of gasoline via a reformer. Meanwhile, NASA begins using General Electric's breakthrough PEMFC on their Gemini space missions. **1968** G.E.'s PEMFC under-performs on Gemini V prompting NASA to award a new contract to Pratt and Whitney for their Alkali Fuel Cells (AFC). The AFCs remain an integral part of Gemini, Apollo and the Space Shuttle.

1970
Building towards the Hydrogen Economy

1970 The term "hydrogen economy" is first used by John O'M. Bockris when talking about a world without petroleum as a fuel. **1973** The OPEC oil embargo prompts many scientists and policy makers to focus on alternative energy sources, including fuel cells. **1993** The first hydrogen powered bus finally hits the streets in Chicago. Soon after, all of the major automobile manufacturers begin prototypes. **1998** Iceland announces a plan to become the first country to become a true "hydrogen economy" by the year 2030. **2001** Ballard produces the first mass-manufactured PEMFC. **2003** $1.2 billion is earmarked by the United States for the development of hydrogen fuel cells. This is closely tied to both the FreedomCAR (a cooperative agreement to speed the production of fuel cell vehicles) and FutureGen (a planned coal plant designed for the production of hydrogen and sequestering of carbon monoxide and dioxide).

Visit these websites for more information

Types of Fuel Cells

http://www.nfcrc.uci.edu/fcresources/FCexplained/FC_Types.htm

Fuel Cells Used by NASA

http://nasaexplores.com/show2_article.php?id=03-058

Hydrogen Economy

http://www.answers.com/topic/hydrogen-economy

Fuel Cell Automobiles

http://www.h2cars.biz/artman/publish/printer_268.shtml

Ballard

http://www.ballard.com/

Freedom Car

http://www.ford.com/en/innovation/engineFuelTechnology/freedomCar.htm

A Brief History of Hydrogen
Element One

Elements are the building blocks that make up the universe. Many elements, such as gold, silver, and lead have been familiar to scientists since ancient times. Other elements were discovered as recently as the 1990's. The Modern Periodic Table of Elements currently lists 114 elements. Of these, 92 are natural elements and 22 are man-made.

Hydrogen was first classified as a distinct element by Henry Cavendish in 1766. It is known as Element 1 because it has one electron and 1 proton making it the first element listed in the Periodic Table. Hydrogen is the smallest and lightest element in the universe, and it is the most abundant. The word hydrogen comes from the Greek words hydro which means "water" and genes meaning "forming." It is estimated that hydrogen makes up over 90% of the total molecules in the observable universe. An important characteristic of hydrogen is that of all of the elements it has the highest energy content per unit of weight.

Hydrogen was used as an energy source for transportation in the early 1900's in zeppelins. The Hindenburg accident slowed the development of the use of hydrogen in transportation. Although it has been shown that the hydrogen in the Hindenburg did not cause the accident and that hydrogen actually burned safely away from the passengers within 60 seconds, the public still had the perception that hydrogen was unsafe.

Today, major utility and car companies recognize the potential of safely using hydrogen for energy. Car companies including General Motors, Ford, Honda, and Toyota have developed hydrogen fuel cell cars. BMW has developed a hydrogen combustion engine. Oil companies like Shell Oil and Chevron-Texaco are beginning to build hydrogen refueling stations so that fuel cell cars can be refueled in gas stations.

com

Visit these websites for more Information

Antoine Lavoisier

http://scienceworld.wolfram.com/biography/Lavoisier.html

http://www.encyclopedia.com/html/l/lavoisie.asp

Nafion

http://www.chemistrydaily.com/chemistry/Nafion

Electrolysis

http://www.wcsscience.com/electrolysis/ofwater.html

http://www.cheminst.ca/ncw/experiments/eelectrowater.

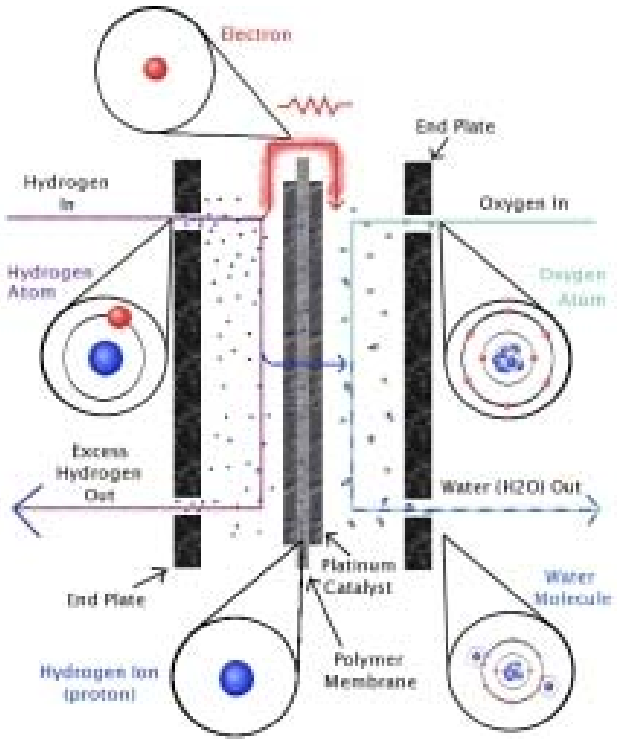
How a PEM Fuel Cell Works

A PEM Fuel Cell converts the chemical energy of hydrogen and oxygen into electrical energy. The fuel cell itself has no moving parts. The heart of a PEM Fuel Cell is a polymer (perflorinated sulfonic acid polymer) called a Proton Exchange Membrane (also known as Polymer Electrolyte Membrane) which acts as an electrolyte. Platinum is attached to the membrane as a catalyst.

When a hydrogen molecule with one negative electron and one positive proton is introduced to the membrane, the platinum along with the membrane creates an environment that allows the positive proton to pass through the membrane, but the negative electron does not pass through. The electrons begin to move along a path creating electricity that is captured as the electron moves around the circuit through a current collector to the other side of the fuel cell. The electron re-joins a proton and the newly formed hydrogen atoms join oxygen to produce water. This reaction also generates heat. So, the output of a hydrogen PEM fuel cell is 1) electricity, 2) heat, and 3) pure, clean water.

The amount of current produced in a fuel cell is dependent on the active area of the MEA (membrane electrode assembly—or the polymer plus the platinum). The amount of voltage produced is usually around .85 volts (- at best– 1.23 volts). So, in order to increase the amount of power required, the size of the MEA is increased. To increase the voltage, fuel cells are joined together in series to create fuel cell stacks.

PEM FUEL CELL

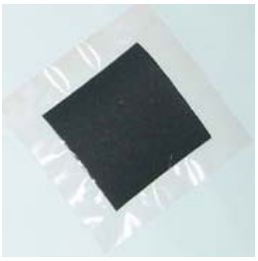


Anode Reaction: $2H_2 \rightarrow 4H^+ + 4e^-$

Cathode Reaction: $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

Overall Reaction $2H_2 + O_2 \rightarrow 2H_2O$

Parts of a PEM Fuel Cell



Membrane Electrode Assembly (MEA)

The Membrane Electrode Assembly (MEA) consists of the perflorinated sulfonic acid polymer membrane, PEM, and the platinum catalyst. Protons can pass through the membrane, electrons are directed around an electrical circuit. Nafion® by Dupont has been the leading membrane in the market although companies such as GEFC and GORE are now producing popular polymer membranes as well. Research is being conducted to find materials to combine with or take the place of platinum as the catalyst to decrease the cost of the fuel cell.

Graphite Plate with Serpentine Flow Channel

Graphite plates are used on both the hydrogen (anode) and oxygen (cathode) side of the fuel cell. Channels are usually machined into the graphite so hydrogen and oxygen are distributed evenly across the MEA.

4 Cell PEM Fuel Cell Stack

Fuel Cell Stack A single cell of a fuel cell consists of an MEA and graphite plate. Each cell produces about .85 volts regardless of the size of the MEA or the amount of catalyst. The wattage produced by a fuel cell depends on the amount of platinum catalyst on the active area of the fuel cell. So, individual cells are layered into fuel cell stacks to produce the balance of voltage and wattage required.

Electrolysis
A Process for Producing Hydrogen

Electrolysis is the process of converting electrical energy into chemical, potential energy. In the 1780's scientist Antoine Lavoisier discovered a way to split water molecules into hydrogen and oxygen and then recombine the them to make water again. When a chemical charge is applied to water, the charge breaks the chemical bond between the hydrogen and oxygen and splits apart the atomic components, creating charged particles called ions.

An electrolyser has two electrodes where the ions form. One electrode, called the anode, is positively charged. The other electrode is called the cathode and is negatively charged. Hydrogen gathers at the negative cathode, and the positively charged anode attracts oxygen. A voltage of about 1.6 is required for electrolysis to take place. This voltage requirement increases or decreases with changes in temperature and pressure. Adding an electrolyte such as salt to water increases the rate at which hydrogen and oxygen are produced.

Reversible fuel cells can be used to perform electrolysis. In a fuel cell, the electrolyte is a substance called Nafion® and is part of the fuel cell membrane assembly. When you apply current to a fuel cell, it will electrolyze water giving you hydrogen on the cathode side and oxygen on the anode side.

Visit these websites for more Information

Antoine Lavoisier

http://scienceworld.wolfram.com/biography/Lavoisier.html

http://www.encyclopedia.com/html/l/lavoisie.asp

Nafion

http://www.chemistrydaily.com/chemistry/Nafion

Electrolysis

http://www.wcsscience.com/electrolysis/ofwater.html

http://www.cheminst.ca/ncw/experiments/eelectrowater.html

$$2H_2O + Energy = 2H_2 + O_2$$

Experiment 1

Electrolysis

Introduction

In this experiment you will produce hydrogen and oxygen using a reversible fuel cell. You will observe the volume of hydrogen produced compared to the volume of oxygen produced.

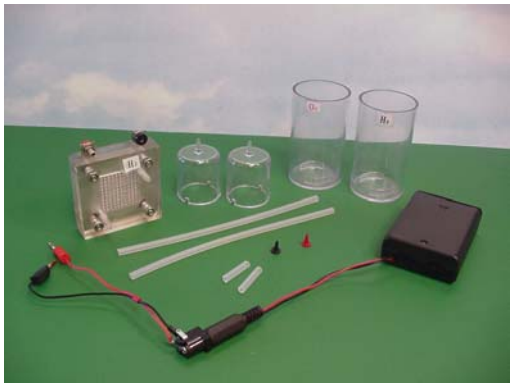
Preparation

.

Prepare the lab documentation sheet on page 20.

Answer questions 1-3.

Prepare your Equipment



Distilled Water 100 ml
PEM Reversible Fuel Cell
Oxygen storage cylinder
Hydrogen storage cylinder
Power supply
Silicon tubing - 2 pieces 3"long, 2 pieces 8"long
Electric cables/wires
Syringe

Electrolysis Experiment

Set-up:

Step 1

Attach a short section of tubing to the bottom nozzle on the Hydrogen (H2 - red) side of the fuel cell. Repeat on the Oxygen (O2- black) side. Do not plug the tubing yet.

Step 2

Using the syringe, push water into the hydrogen side of the fuel cell through the lower tube until you can see that the reservoir is full. Plug the tube. Repeat on the oxygen side.

Step 3

There are two storage cylinders. One is for hydrogen, and the other is for oxygen. Each cylinder has a small inner cylinder that reaches about half way up each storage cylinder. Remove the inner cylinder from the outer cylinder. Attach a long piece of tubing to the top of the inner cylinder on the hydrogen inner cylinder. Attach a long piece of tubing to the top of the inner cylinder on the oxygen inner cylinder.

Electrolysis Experiment

Step 4

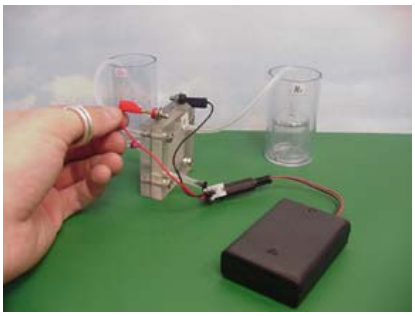
Pour distilled water into the outer cylinder up to the 0ml mark. Fit the inner cylinder snuggly into the outer cylinder capturing water in the inner cylinder. Push down on the inner cylinder to be sure the cylinder is fitting tightly onto the rim at the bottom of the outer cylinder. There is a small gas outlet on the edge of the inner cylinder. Be sure to allow the gas to escape from the inner cylinder into the outer cylinder. Do not block the outlet with the plastic rim on the bottom of the outer cylinder.

Step 5

Attach the tubing from the hydrogen cylinder to the top inlet on the hydrogen side of the fuel cell. Repeat on the oxygen side of the cylinder.

Step 6

Insert 2 AA Batteries into the power supply.
Attach your power source to the fuel cell. Connect the red wire to the red jack on the fuel cell and the black wire to the black jack on the fuel cell. Turn the battery pack on.



Electrolysis Experiment

Step 7

You will immediately see water in the cylinder being displaced to the top of the cylinder. Hydrogen and oxygen are being captured in the inner cylinders. Hydrogen and oxygen are invisible, so you will be recording what looks like empty space as water is pushed by hydrogen from the inner cylinder to the outer cylinder.

Step 8

Begin your measurements. Record the amount of hydrogen and oxygen produced every 30 seconds for 5 minutes

Step 9

Disconnect the battery pack from the fuel cell. Turn the battery pack off.

Step 10

Complete Lab Sheet

Lab Documentation
Electrolysis

In this experiment you will produce hydrogen and oxygen using a reversible fuel cell. You will observe the volume of hydrogen produced compared to the volume of oxygen produced.

1. What is the chemical symbol for hydrogen?

2. What is the chemical symbol for oxygen?

3. When you use electrolysis to separate water, what do you predict the ratio of hydrogen to oxygen will be?

Lab Documentation Sheet

Time Elapsed			Ratio of Hydrogen to Oxygen
.5 min.			
1 min.			
1.5 min.			
2 min.			
2.5 min.			
3 min			
3.5 min			
4 min			
4.5 min			
5 min			

4. Which gas was produced more quickly?

5. What is the ratio of hydrogen to oxygen in water?

6. What is the chemical symbol for water? What does that symbol mean?

Experiment 2

Does Oxygen Increase the Efficiency of PEM Fuel Cell?

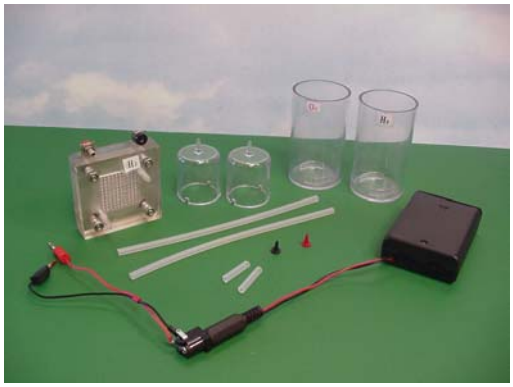
Introduction

In this experiment you will evaluate the use of oxygen in a reversible fuel cell. You will compare the productivity of the fuel cell with oxygen compared to the productivity of the fuel cell when oxygen is not used.

Preparation

.

Prepare the lab documentation sheet on page 24.
Answer questions 1-3.

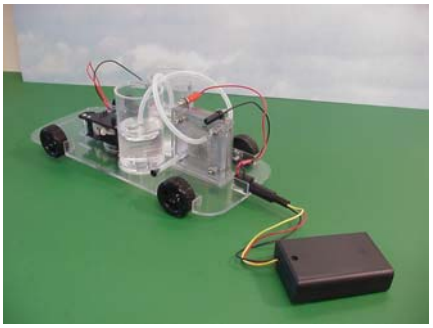


Prepare your Equipment

Distilled Water 100 ml
PEM Reversible Fuel Cell
Oxygen storage cylinder
Hydrogen storage cylinder
Power supply with batteries
Silicon tubing - 2 pieces 3"long, 2 pieces 8"long
Electric cables/wires
Syringe
Two books to hold the car in the air.

Oxygen Experiment

Set-up:

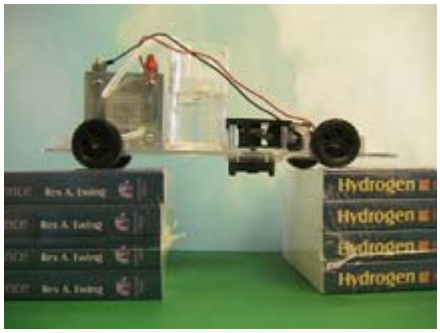


Step 1

Follow steps 1—10 in the Intelligent Car Instructions section of this manual.

Step 2

Plug the red and black wires from the car chassis into the banana jacks on the fuel cell. Prop the car chassis between two books so the drive wheel is in the air and the car does not move. (This will allow you to have more consistent results which will not be affected by the resistance caused by the surface area or number of turns the car needs to make.)



Step 3

Begin a stop watch. Note the amount of time it takes for the motor to stop moving. Unplug the wires from the chassis to the fuel cell.

Step 4

Release any remaining hydrogen and oxygen in the inner cylinders by disconnecting the long, upper tubes from the fuel cell. When all of the water in the upper gas cylinders has moved back to the bottom of the cylinders reattach the tubes to the top of the inner cylinders.

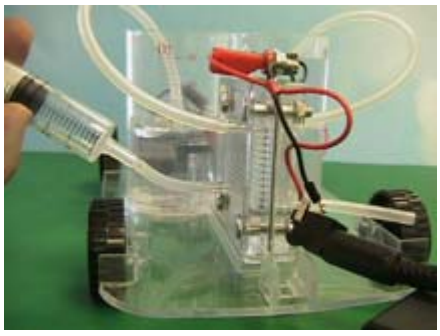
Oxygen Experiment

Step 5

Reattach only the hydrogen side tubing to the fuel cell, leaving the upper nozzle on the oxygen side of the fuel cell open. Remove the small tube on the lower nozzle of the oxygen side of the fuel cell.

Step 6

Attach the power supply to the fuel cell. Insert the red wire into the red banana jack and the black wire into the black banana jack. You will see hydrogen being produced. The oxygen is being released into the air.

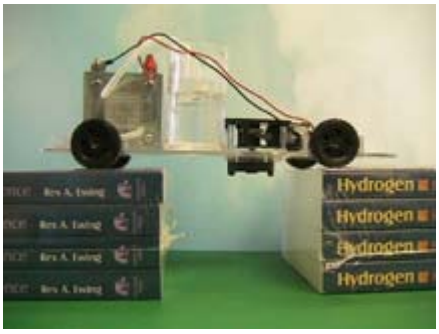


Step 7

When you begin to see hydrogen bubbles released through water in the upper chamber, turn the power supply off and remove the power supply from the fuel cell. Attach the wires from the chassis to the fuel cell.

Step 8

Attach the upper tube from the oxygen cylinder to the top of the oxygen side of the fuel cell. Using your syringe, pull the plunger of the syringe up filling the syringe with air. Push the air through the bottom tube of the fuel cell through the fuel cell and into the inner oxygen cylinder until the inner oxygen cylinder is full of air. Attach wires from the car motor to the fuel cell.



Step 9

Prop the car between two books so the motor can turn freely. Note the amount of time it takes before the motor stops running. Complete your lab sheet.

Lab Documentation
Oxygen Experiment

In this experiment, you will examine the role of oxygen in a PEM Fuel Cell. If you have not already done so, read page 13. How a PEM Fuel Cell Works.

1. What is the purpose of hydrogen in a PEM fuel cell?

2. What is the purpose of oxygen in a PEM fuel cell?

3. In the explanation How a PEM Fuel Cell Works, three types of fuel cells are discussed. One is H2/O2, one is H2/Air and one is H2/Forced Air. Since a fuel cell can operate without oxygen, what do you think will happen when we disconnect the oxygen from this fuel cell?

4. For how long did your fuel cell run with the oxygen attached?

5. For how long did your fuel cell run using air?

6. How would you explain the difference in the times.

7. How would you design this fuel cell differently to have it work better using ambient air without forced oxygen?

Experiment 3

Does Resistance change the Amount of time the PEM Fuel Cell will run the car?

Introduction

In this experiment you will evaluate the effect of resistance on the reversible fuel cell. You will compare the amount of time of the fuel cell will power the car with no resistance to the amount of time the fuel cell will power the car when resistance is added.

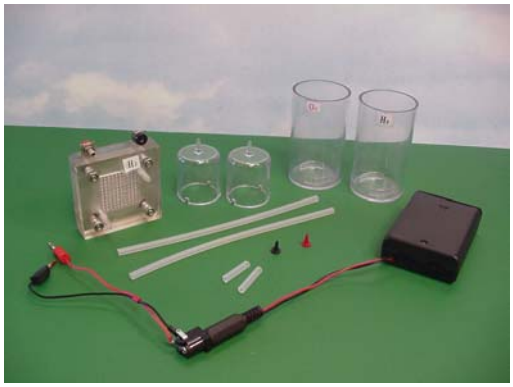
Preparation

.

Prepare the lab documentation sheet on page 28.

Answer questions 1-3.

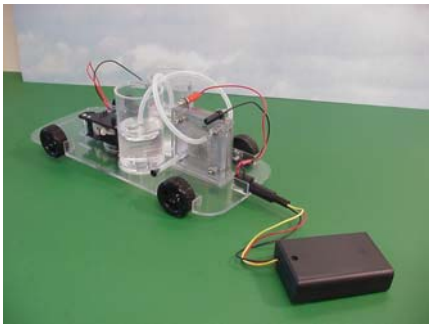
Prepare your Equipment



Distilled Water 100 ml
PEM Reversible Fuel Cell
Oxygen storage cylinder
Hydrogen storage cylinder
Power supply with batteries
Silicon tubing - 2 pieces 3"long, 2 pieces 8"long
Electric cables/wires
Syringe
Two books to hold the car in the air.

Resistance Experiment

Set-up:

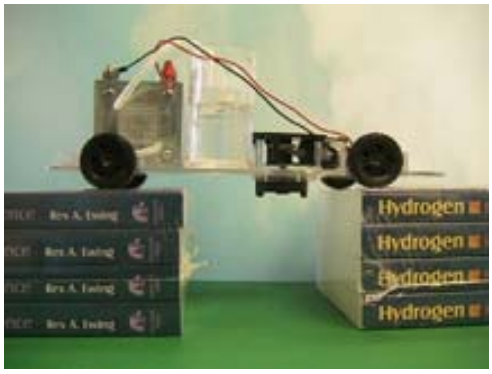


Step 1
Write your prediction on the lab sheet.

Follow steps 1—10 in the Intelligent Car Instructions section of this manual.

Step 2

Plug the red and black wires from the car chassis into the banana jacks on the fuel cell. Prop the car chassis between two books so the drive wheel is in the air and the car does not move. (This will allow you to have more consistent results which will not be affected by the surface area or number of turns the car needs to make.)



Step 3

Begin a stop watch. Note the amount of time it takes for the motor to stop moving. Unplug the wires from the chassis to the fuel cell.

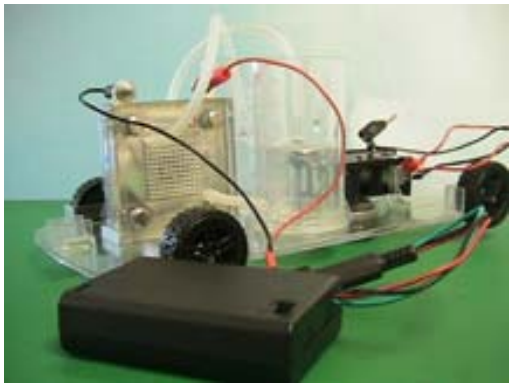
Step 4

Release any remaining hydrogen and oxygen by disconnecting the long, upper tubes from the fuel cell. When all of the water in the upper gas cylinders has moved back to the bottom of the cylinders. Reattach the tubes.

Resistance Experiment

Step 5

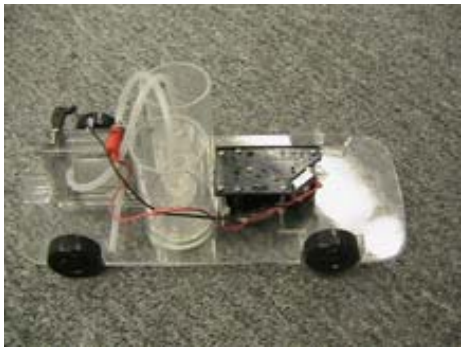
Attach the power supply to the fuel cell. Insert the red wire into the red banana jack and the black wire into the black banana jack. You will see hydrogen being produced again. Note: if you have used the fuel cell 2 or 3 times without adding additional water, you might need to add a small amount of water to the fuel cell on both the hydrogen and oxygen sides.



Step 7

When you begin to see hydrogen bubbles released through water in the upper chamber, turn the power supply off and remove the power supply from the fuel cell. Attach the wires from the chassis to the fuel cell..

Step 8



Put the car on a flat surface and note the amount of time it runs. For additional experiments, count the amount of time the car has to turn. Compare how long the car runs when it turns just a few times to how long it runs when it has to make many turns. Also, compare how long the car runs on a smooth surface such as a wooden floor to how long it runs on a rough surface such as carpeting.

Step 9

Complete your lab sheet.

Lab Documentation
Resistance Experiment

In this experiment you will evaluate the effect of resistance on the reversible fuel cell. You will compare the amount of time of the fuel cell will power the car with no resistance to the amount of time the fuel cell will power the car when resistance is added.

1. Make a prediction: Will the car fun for a longer period of time when it is hanging in the air or when it is running on a surface? Why?

2. How long did your car motor run when it was hanging in the air without any resistance?

3. How long did your car motor run when it was running on a surface?

4. What do you think an ideal surface would be to allow the car to run longer?

5. Why do you think the car runs for less time when it has to make more turns?

6. What adjustments could you make to the design of the car to make it run longer on a surface that offers resistance?

Ohm's Law

Georg Simon Ohm was a Bavarian physicist who is credited for developing the mathematical formulas for electrical current. Ohm's law recognizes the relationship between voltage (V), Current (I), and Resistance (R). The basic equations formed by Ohm's Law is: V=IR. When we measure electricity we usually denote current as amperes (amps) and resistance as ohms.

Working from Ohm's Law we can also define the amount of electric power being produced. The equation for finding power is: P=VI. Power is measured as Watts. Using the equations below you can find the watts, amps, and voltage of your fuel cell.

Watts Divided by Volts - Amps

Watts Divided by Amperes = Volts

Volts Divided by Amperes = Ohms

Volts times Amperes = Watts

Single slices of fuel cells can produce only about .85 volts. The amount of current (or amps) produced by the fuel cell depends primarily on the area and amount of catalyst on the Proton Exchange Membrane. Fuel cell manufacturers design fuel cells based on the user's requirements for volts, watts, and amps by varying the size of the fuel cell and the number of fuel cell slices in a fuel cell stack.

Experiment 4
Ohm's Law

Introduction

In this experiment you will calculate the number of watts being produced by your fuel cell using equations derived from Ohm's Law .

Preparation

.

Prepare the lab documentation sheet.
Answer questions 1 and 2.

Prepare your Equipment

Multi-meter (not included in kit)
Distilled Water 100 ml
PEM Reversible Fuel Cell
Oxygen storage cylinder
Hydrogen storage cylinder
Power supply
Silicon tubing - 2 pieces 3"long, 2 pieces 8"long

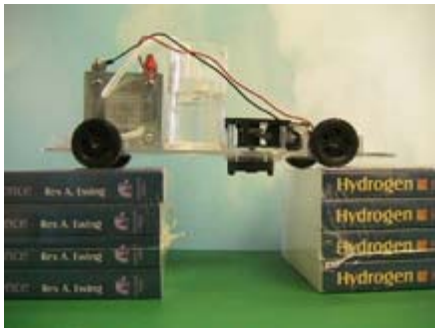
Step 1

Follow steps 1—10 in Operating Instructions in this manual to produce hydrogen and oxygen.

Ohm's Law Experiment

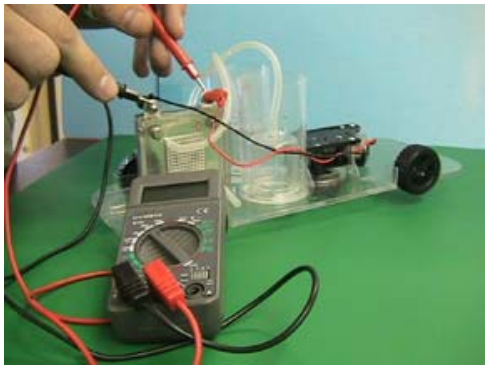
Step 2

Prop the Intelligent Car chassis between two books so the motor is able to turn freely without the car moving. You are going to be taking measurements , so the car must remain stationary.



Step 3

Attach the wires from the chassis to the fuel cell. Insert the red wire into the red banana jack and the black wire into the black banana jack. (Note: It is important that you follow these instructions carefully because if you reverse the red and black wires you will destroy the fuel cell)



Step 4

Turn the multimeter dial to measure amps in the 200 mA range. Touch the red lead from the multimeter to the screw at the back of the red banana jack on the fuel cell. At the same time, touch the black lead from the multimeter to the screw at the back of the black banana jack on the fuel cell. Note the number of mA being produced by the fuel cell on Question 3 on your Lab Sheet.

Ohm's Law Experiment

Step 5

Turn the dial on your multimeter to measure volts in the .200 range. Touch the red lead from the multimeter to the screw at the back of the red banana jack on the fuel cell. At the same time, touch the black lead from the multimeter to the screw at the back of the black banana jack on the fuel cell. Note the number of Volts being produced by the fuel cell on Question 4 of your Lab Sheet.

Step 6

Disconnect the multimeter leads from the fuel cell. Turn the multimeter off. Disconnect the car motor from the fuel cell.

Complete your Lab Sheet.

Lab Documentation
Ohm's Law

In this experiment you will calculate the number of watts being produced by your fuel cell using equations derived from Ohm's Law.

1. What is Ohm's Law?

2. What equation will you use to calculate watts if you have measurements for volts and amps?

3. How many amps is your fuel cell producing? (Note that the amps you measured on your multimeter are reported on the digital display as milli-amps, so be careful with your decimal point when making your calculations.)

4. How many volts is your fuel cell producing?

5. Calculate the watts being produced by your fuel cell.

6. If you have a fuel cell that produces .85 volts at 2 watts, how many amps is the fuel cell producing?

7. A single fuel cell usually produces about .85 volts, how many fuel cells would you need to stack together to run a radio that requires 6 volts?

Glossary of Terms

Alkaline Fuel Cell	Fuel Cell that uses an alkaline solution (the opposite of acidic) as the electrolyte. Common alkaline solutions used include salt and KOH
Alternating Current	A current which periodically changes or reverses it direction of flow
Amperage	A measure of electrical potential named after the 19th century French physicist Andre Marie Ampere. It is commonly represented with the symbol A or amp.
Anode	The point where electrons exit from a device to the external electric circuit. In a fuel cell the anode is the hydrogen side. When the fuel cell is used as an electrolyser, the anode is the oxygen side.
Atom	The basic building blocks of matter. They cannot be chemically subdivided by ordinary means. Atoms are composed of protons, neutrons, and electrons.
Catalyst	A substance that begins or increases the speed of a chemical reaction. In PEM fuel cells, the catalyst is usually platinum.
Cathode	The point where electrons enter a device In a fuel cell the anode is the oxygen side. When the fuel cell is used as an electrolyser, the cathode is the oxygen side.
Charge	Charge is the imbalance of positive and negative electricity flowing through matter.
Circuit	A complete pathway for electricity to flow.
Current	Flow of electricity between two points. Measured in amps.
Diode	A device having two terminals with a low resistance to current in one direction and a high resistance in the other direction. Diodes can be used on fuel cells to protect against current flowing the wrong way if leads are attached incorrectly.
Direct Current	A current that flows steadily in one direction Fuel cells produce direct current.

Distilled Water	Water that has been heated until it becomes steam, leaving impurities behind, then cooled again from steam to liquid.
Efficiency	The ratio or percentage of the amount energy used compared to the amount of energy created. Efficiency can be represented by the equation: **% efficiency = useful energy produced x 100 / total energy used**
Electrode	A conductor used to make electrical contact with some part of a circuit Fuel Cells use MEA's - membrane electrode assemblies which are usually a polymer membrane with a platinum catalyst.
Electrolysis	The breaking down of water into hydrogen and oxygen
Electron	An elementary particle with a negative charge In fuel cells, the electron travels around the electric circuit.
Energy	Energy is the ability to do work. Fuel cells transform chemical potential energy into electrical energy.
Fossil Fuel	Any combustible organic material, such as coal, oil, or natural gas which is derived from the remains of former life held in the earth's crust.
Fuel Cell	A battery-like device that transfers chemical potential energy into electricity using hydrogen as the fuel and oxygen and other elements as catalysts.
Hydrogen	The simplest and lightest and most abundant element. Element one in the Periodic Table of Elements. It contains one proton and one electron.
Ion	An atom or group of atoms in which the number of electrons is different from the number of protons. In a fuel cell, the proton is the hydrogen ion which passes through the Proton Exchange Membrane.
MEA	Membrane Electrode Assembly. The polymer membrane plus the platinum catalyst in a fuel cell.
Methanol	A colorless, toxic, flammable liquid rich in hydrogen (CH_3OH) used as a fuel in methanol fuel cells
Molecule	The smallest particle of a pure chemical substance that still retains its chemical composition and properties
Multimeter	Electronic test equipment used to make various measurements such as voltage, current, and resistance

Ohm's Law	Defines the relationship between voltage and current in an ideal conductor. Ohm's Law states that: The potential difference (voltage) across an ideal conductor is proportional to the current through it. The constant of proportionality is called the resistance, R I is the current flowing through the resistance So, Ohm's Law is given by the equation: V= IR
Oxygen	An odorless, colorless gaseous element with the atomic number 8
PEM	Proton Exchange Membrane or Polymer Electrolyte Membrane It is the polymer in the heart of a fuel cell through which the hydrogen proton passes
Polymer	A compound derived either by the addition of smaller molecules, or by the condensation of smaller molecules through dehydration. The polymer used in fuel cells is usually formed by eliminating alcohol from a solution.
Power	The product of voltage and current
Proton	A subatomic particle that has a positive electric charge. In a PEM fuel cell, the proton from a hydrogen atom passes through a polymer leaving the electron to go around a circuit.
Renewable Energy	Naturally occurring, theoretically inexhaustible source of energy, such as hydrogen, biomass, solar, wind, tidal, wave, and hydroelectric power, that is not derived from fossil or nuclear fuel.
Resistance	A material's opposition to the flow of electric current. Resistance is measured in ohms. It can be found using the equation R =V/I where V represent voltage and I represents current (amperes).
SOFC	Solid Oxide Fuel Cell A fuel cell that operates at extremely high temperatures
Voltage	A measure of electrical potential
Wattage	A measure of the amount of electrical power provided by the circuit. The product of voltage and amps. Watts = Volts x Amps

Suggested Answers to Experiments

Experiment 1—Electrolysis

1. H
2. O
3. Prediction—answers will vary
4. Hydrogen
5. 2:1
6. H20; there are two hydrogen atoms and one oxygen atom in a water molecule

Experiment 2—Oxygen in a fuel cell

1. Hydrogen is the fuel; it provides the electrons that create electricity.
2. Oxygen helps the process by joining the hydrogen to make water.
3. Prediction—answers will vary
4. Answers will vary—the range should be between 3 and 5 minutes
5. Answers will vary—the range should be between 30 seconds and 2 minutes
6. There is more oxygen to attract the hydrogen molecules, when air is used, there are elements other than oxygen present that do not help the process
7. Answers will vary—the design should make it easier for air to pass through the

Experiment 3—Resistance

1. Prediction—answers will vary
2. Answers will vary—the range should be between 3 and 5 minutes
3. Answers will vary—the range should be between 1 and 4 minutes
4. Answers will vary— Suggested answer: smooth surface
5. It requires more energy to turn than to go straight because turning increases the amount of resistance
6. Answers will vary—Suggested answer: change the gear ratio, change the size or material of the wheels, reduce the weight of the fuel cell

Experiment 4—Ohm's Law

1. V=IR
2. V ◦ A = W
3. Answers will vary—the range should be between 250 and 400 mA
4. Answers will vary—the range should be between .75 and .95 V
5. Answers will vary—the range should be between .25 and .35 watts
6. 2.35 A
7. 7 single cells

National Science Teachers Association Standards Addressed by experiments in this manual.

K-4

- Science and technology have been practiced by people for a long time.
- Men and women have made a variety of contributions throughout the history of science and technology.
- Materials can exist in different states--solid, liquid, and gas. Some common ma terials, such as water, can be changed from one state to another by heating or cooling.
- Some resources are basic materials, such as air, water, and soil; some are pro duced from basic resources, such as food, fuel, and building materials; and some resources are nonmaterial, such as quiet places, beauty, security, and safety.
-

5-8

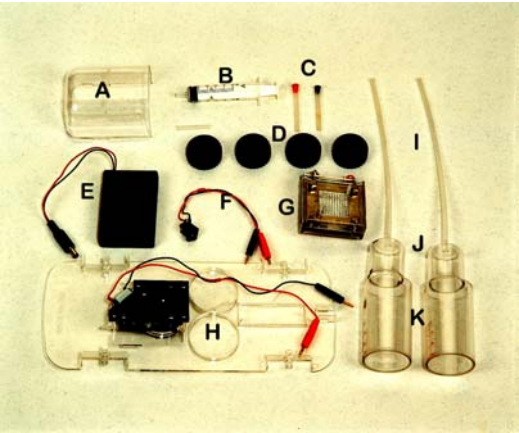
- Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties.
- In chemical reactions, the total mass is conserved. Substances often are placed in categories or groups if they react in similar ways; metals is an example of such a group.
- Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical.
- Energy is transferred in many ways.
- Science and technology are reciprocal. Science helps drive technology, as it ad dresses questions that demand more sophisticated instruments and pro vides principles for better instrumentation and technique. Technology is essential to science, because it provides instruments and techniques that en able observations of objects and phenomena that are otherwise unobserv able due to factors such as quantity, distance, location, size, and speed. Technology also provides tools for investigations, inquiry, and analysis.
- Many individuals have contributed to the traditions of science. Studying some of these individuals provides further understanding of scientific inquiry, science as a human endeavor, the nature of science, and the relationships between science and society.

9-12

- Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. The accuracy and precision of the data, and therefore the quality of the explora tion, depends on the technology used.
- Scientific explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions and possible modification; and it must be based on histori cal and current scientific knowledge.
- Matter is made of minute particles called atoms, and atoms are composed of even smaller components. These components have measurable properties, such as mass and electrical charge. Each atom has a positively charged nucleus surrounded by negatively charged electrons. The electric force be tween the nucleus and electrons holds the atom together.
- An element is composed of a single type of atom. When elements are listed in or der according to the number of protons (called the atomic number), repeating patterns of physical and chemical properties identify families of elements with similar properties. This "Periodic Table" is a consequence of the repeat ing pattern of outermost electrons and their permitted energies.
- A large number of important reactions involve the transfer of either electrons (oxidation/reduction reactions) or hydrogen ions (acid/base reactions) be tween reacting ions, molecules, or atoms. In other reactions, chemical bonds are broken by heat or light to form very reactive radicals with electrons ready to form new bonds. Radical reactions control many processes such as the presence of ozone and greenhouse gases in the atmosphere, burning and processing of fossil fuels, the formation of polymers, and explosions.
- Science often advances with the introduction of new technologies. Solving tech- nological problems often results in new scientific knowledge. New technolo gies often extend the current levels of scientific understanding and introduce new areas of research.

Intelligent Fuel Cell Car

Parts and Supplies



ADD FLASHING RED LIGHTS TO YOUR FUEL CELL CAR

Letter	Product Number	Description	Price For one	Price each for 10 or more
		Intelligent Car Kit	$79.99	$53.00
G		Fuel Cell	$49.99	$35.00
L		Solar Panel	$19.95	$17.95
M		Flashing Lights	$17.95	$15.00
E & F		Power Pack	$12.95	$ 9.95
K		Set of Storage Cylinders	$10.25	$ 7.25
D		Wheels	$ 2.25	$ 2.25
A		Plastic Motor Cover	$ 2.25	$ 2.25
I		Tubing—2 feet	$ 2.25	$ 2.25
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